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Eco-balance and Sustainability of Electric Vehicles – A Contribution to the „Clean and Green“ Discussion

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Abstract:

We live in a dynamic mobility transition phase that compliments the energy transition (Energiewende) towards abandoning fossil-based fuels. The future mobility eco system is "CASE" – connected, automated, shared, electric. In 2017 electric vehicles sales reached a tipping point and sales in Germany doubled. New models at reasonable prices are announced for the coming years and infrastructure is being installed to meet the demand putting electric mobility within reach for the masses. While the discussion about air quality in cities, traffic noise and Diesel bans is still all around and no solution at hand, the benefit of electric vehicles on the other hand is questioned. A holistic analysis of various studies on the eco-balance and CO2 footprint of EVs shows that already today every km driven electric has a positive impact on the climate. With the continuing energy and mobility transition individual mobility will be decarbonized sustainably. This will not be possible without electric powertrains.

JEL Classification: M31 (Marketing)

Keywords: Electric vehicle, EV, electric mobility, eco-balance, CO_2 footprint, sustainability, circular economy, battery technology, power supply, electricity generation, energy supply, Energiewende, Verkehrswende

1 Introduction

Despite year-long efforts in emission reduction and politics commitment to targets, with e.g. the Paris climate agreement, the traffic sector is clearly lacking behind. The energy transition rather seems a question of "when". In the traffic transition discussion on the opposite, the debate is still a lot more about "how". Whole industries are endangered and resistance to disruptive change on one side meet new powerful players seeing their chances on the opposite side. The "CASE" future of mobility – connected, automated, shared, electric – promises completely new mobility eco systems.

One aspect is the transition to alternative powertrain systems. After the Diesel scandal has shattered trust in industry and conventional powertrain technology, electric mobility has been pushed forward. Just recently, environmental legislation has again been tightened in Europe and more and more City bans for combustion engine cars are enforced.

In 2017 electric vehicles sales reached a tipping point and sales in Germany doubled. With continued growth world-wide seen in 2018, in 2019 and 2020 e-mobility is expected to see an even stronger boost. New models at reasonable prices are announced and infrastructure is being installed to meet the demand for the coming years. This puts electric mobility within reach for the masses.

However, whether this concept will prevail is difficult to predict. Disruptive forces and end customer behavior are playing a decisive role. But currently customers and politics alike show a high level of insecurity about right or wrong. This makes predictions and forecasts rather difficult.

One discussion that contributes to this insecurity is about the benefit of electric vehicles to climate change.

1. 'EV batteries carry a heavy ecologic rucksack from production that cannot be amortized'
2. 'EVs are not green as long as we produce dirty coal power to charge them'

These are the two most provoking and most relevant theses in this context.

After giving an overview of the concept of sustainability and eco-balance with respect to the mobility transition these two theses about the ecologic impact of electric vehicles will be discussed. A focus will be on the public perception and the validity of studies and calculations contributing to opinion making.

The identification of the key factors for future sustainable development of electric mobility is straight forward. However, it can be conveyed that the criteria of the past do not serve well the evaluation of new and future concepts. Benchmarking should follow new approaches, too. A pragmatic entry will be proposed. Insights into current developments will give an outlook on the future.

Conclusions based on a higher-ground perspective will be drawn to contribute to the big picture. They allow for an optimistic and future-oriented view on the topic.

2 Eco-balance and sustainability of Electric Vehicles

There have been many studies around in recent years about the potential impact of battery and EV production on climate change as well as on EV emissions over lifetime. This survey presents an excerpt of the ones most prominently discussed in the media, since this influences the public opinion and customer behaviour.

The motivation is to show the spectrum of arguments and varying depth of analysis behind some prominent claims. The public discussion was very controversial but not always well covered back-to-back with research or distinct scientific results.

Therefore, this analysis is not comprehensive and explicitly does not pretend to meet scientific standards. It is meant to give a generic overview of the main arguments used.[1]

2.1 Eco-balance concept

The concept of a circular economy is more and more embraced already in the design of products. The thinking in product lifetime and the ecologic impact of resource depletion, production, utilization and disposal at the end of life or recycling of components and materials is a matter of course today. Legislation demands documentation and sets certain standards.

The analysis of the ecological impact of products over their lifetime from “cradle-to-grave” in a life cycle assessment (LCA) has been standardized. A simplified and linear scheme is shown in Figure 1.

However, different forms of eco-balances may reflect the ecological aspects of a single product or provide a benchmark of several products or they integrate a holistic evaluation including economic, technical and/or social aspects.

[1] After concluding this survey many more studies and meta studies on the eco-balance and environmental footprint of EVs have been published. Most follow a similar approach than the selected reports. The discussion continues rather controversial.

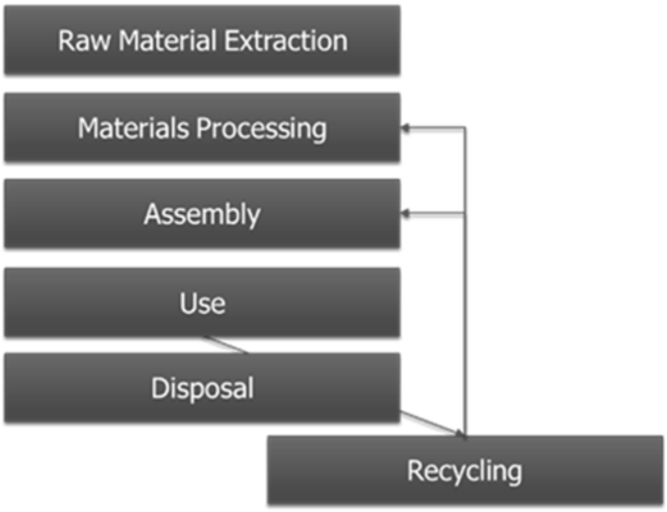

Figure 1

A typical Life Cycle Assessment (LCA), as usually conducted for material production, e.g. in the Chemical Industry, considers various impact factors from cradle-to-gate, cradle-to-grave or cradle-to-cradle. The categories analysed are:

- Use of primary energy
- Global Warming potential (GWP)
- Acid potential
- Photochemical oxidant formation
- Ozone depletion
- Resource depletion

For the purpose of measurement and comparison, the different factors are converted into CO_2 equivalents (CO_2eq) to make up for a standardized value. Sometimes the term GHG for greenhouse gas is used as well as umbrella term for types of emissions.

2.2 Elements of Electric Vehicle life-time emissions

Theoretically, the evaluation of the climate impact of a vehicle requires the separate analysis and then addition of several steps in the lifetime of the product. One could understand this as the addition of several cradle-to-gate steps – the gate-product of one step being the cradle-entry to the next step. The value chain of a vehicle over its lifetime is shown in Figure 2, naming the relevant aspects with an impact on emissions of each step.

Figure 2

The complexity of cars already asks for comprehensive analyses in steps 1 and 2. The contribution of maintaining a dealership network and distributing cars from one production site to manifold sales sites is hard to assess and seldom documented.

Step 4, vehicle utilization itself, on the other hand is standardized in the form of energy efficiency rating. For the customer behaviour many statistics are available, and average mileage and fuel consumption is well documented. Quite often the contribution of fuel supply is not being reported in statistics. Also, the end-of-life fate of a car usually remains rather in the dark.

Based on experience with gasoline or diesel cars, statistics and reports are being used – “historical evidence” so to say. Since there is not much data available for EVs yet, some field test reports with a small number of probands and protoypes is used and often generalizations, assumptions and projections to the future are combined with facts and figures from the past.

As already introduced with the two main critiques, EVs are especially seen in the context with the electricity consumed. Of course, this is also the main motivation: decarbonization. However, the benchmark on energy source level and emissions requires comparing two different systems with different generation and distribution patterns: electricity and fuel. This needs to be kept in mind when looking at the whole picture.

2.3 Benchmark: ICE

The studies analysed typically compare Electric Vehicles (EV) with conventional cars, that is Internal Combustion Engine vehicles (ICE), either gasoline or diesel cars.

Sometimes also Plug-In Hybrid Vehicles are compared (PHEV). Current PHEV hybrid cars usually combine two powertrains in a parallel configuration, one electric system, that typically allows for 50 km electric range, and a separate gasoline propulsion system. In that case electricity as well as fuel consumption needs to be accounted for in the utilization phase.

2.4 Evaluation criteria for comparison of studies

For the purpose of comparing the different articles and studies a simplified concept for evaluation was developed based on the value chain described above. The generic evaluation criteria are shown in the checklist, see Table 1.

Check-List
Emissions from raw material production considered
Emissions from production and transportation calculated
Carbon footprint of battery included
Similar vehicle type/-class compared
Mileage realistic
Supply of fuel considered
Local electricity mix applied
End of live considered – scrapping/recycling

Table 1

3 Survey of studies and their findings

The recent reports about the potential impact of battery and EV production on climate change as well as on EV emissions over lifetime are contradictory and disputed. Often, the nature of the questions analysed in the studies or reports can be seen in the context of the commissioner of the study. What in the media is referred to, often is an excerpt, sometimes followed by another analysis or interpretation of the journal authors and their key message.

This survey compares five reports most prominently discussed in the media: It is not comprehensive and explicitly does not pretend to meet scientific standards. It is meant to give a generic overview of the main arguments used.

3.1 Danish Journal Ingeniøren/IVL

The study that initially prompted this survey, because it raised so much public interest, was reported about in Ingeniøren, a Danish journal. Their report is based on a more fundamental analysis done by the IVL, the Swedish Environmental Institute, commissioned by the Swedish Energy Agency and the Swedish Transport Administration.

The IVL study analyses EV battery production in China only. The Ingeniøren authors combine their findings with a mileage assumption for driving in Scandinavia and the supply of fuel/electricity. The local electricity mix is not applied in their calculation and the vehicle classes compared are not similar.

The authors claim that a Tesla (100 kWh) brings a heavy CO_2 rucksack from production of 17.5 Tons CO_2eq.[2] It would take 8 years to compensate for by driving electric compared to a conventional car. A Nissan Leaf with 30 kWh would carry 5.3 Tons CO_2eq. The authors also compare this with the 600 kg CO_2eq that a return flight from Stockholm to New York would account for.

Their conclusion is not to drive around with too large batteries when not needed, e.g. for inner City and short distance driving.

3.2 Carnegie Mellon Study

A study at Carnegie Mellon University was commissioned by Scientific American. Different States in the US were analysed in view of the quality of electricity supply and its suitability for electric driving with either a PHEV or a battery electric vehicle (BEV) or a gasoline car. A Chevy Volt, a Toyota Prius (both PHEV) were compared with a Nissan Leaf (BEV) and a gasoline Mazda 3. These are comparable vehicles from the same segment of compact cars.

The study highlights the local annual emissions in the States analysed and conclude that even the time of day for charging counts. The analysis is based on tank-to-wheel data only.

In general, they find that Hybrid cars produce the least emissions for the specific regions. And the overall summary is: Do not drive EVs in States with high fossil power share.

3.3 IFEU Study

The IFEU Institute study was commissioned by Handelsblatt and UBA (Umweltbundesamt). It compares vehicles in the compact class without disclaiming details, they rather use a generic draft design for providing an independent base for the comparison of different powertrain concepts. The region analysed is Germany. This study is comprehensive in that respect that all aspects from the checklist are tackled.

Total CO_2eq for production, service and disposal of cars are calculated, supply of fuel or electricity and tailpipe emissions are added.

The authors discuss the impact on emissions of the actual electricity mix in Germany and the trends towards 2030 with the targets set for the Energiewende.

[2] The IVL study calculates energy consumption for a battery production in China. This accounts for a rather high value due to a contribution of coal power to the Chinese energy mix. Other studies use data from the International Energy Agency (IEA) or the US Ministry of Energy. The site of production and also transportation emissions may play a crucial role.

The authors conclude, that during production of an EV 50 % more GHG (greenhouse gas) emissions are generated. Over lifetime EVs emit 31 % less than gasoline and 12 % less than diesel cars. PHEV are not favourable – emissions are slightly higher than that of a diesel today and would be slightly lower in 2030.

According to this study, the CO_2eq rucksack amounts to 10.7 tons for the EV with 200 km range and 7.2 tons for the gasoline or diesel car calculated (compare the values in the Ingeniøren calculation of 5.3 for Nissan Leaf and 17.5 for Tesla Model S). A vehicle mileage of 169,000 km over 13 years is assumed.

While ICE cars in total contribute 29.2 tons CO_2eq to emissions, this value is 25.8 tons for EVs in 2017 and 17.4 tons in 2030 respectively.

In summary: Electric Vehicles are only as clean as the electricity consumed.

3.4 MIT/Trancik Lab

The German Manager Magazin cites a study from the MIT (Massachusetts Institute of Technology, the lab of Professor Trancik who developed a “carboncounter”) with a comparison of a Tesla Model X P100D, a Ford Fiesta and a BMW X5 for their use in Germany. Most criteria from the check-list are considered, except for the end-of-life aspect. Merely the vehicle types compared are quite different – on purpose – the authors wanted to know whether a small gasoline car could beat a large EV. Real data available at MIT for production and utilization of the cars is used to account for comparable boundary conditions.

The authors calculate 13 tons CO_2eq to produce the Tesla[3] and 5 tons for the Fiesta. This then emits 34 tons on 175,000 km and the EV only 22 tons (calculated with today’s German energy mix).

The benefit of recuperation is discussed in the article. The energy efficiency of EV powertrains in general explain a better result of the heavy Tesla compared to the BMW SUV. Only a small Diesel could possibly beat the Tesla, speculates the researcher, but the data is not available at the lab.

Renewable electricity in production will even improve the result for the Tesla in the future (referring to the Gigafactory concept being CO_2-neutral in production).

The authors claim: A fat Tesla is cleaner than a small Ford.

[3] This is considerably less than the other authors state, although Model X and Model S differ slightly, both carry the same battery size, that contributes at large to the value.

3.5 VUB University of Belgium

The Guardian presents the results of a study by the VUB University of Belgium, commissioned by the T&E Think Tank. They are comparing the emissions in different European countries and focus on the local electricity mix applied. The vehicle types calculated and compared are not known. Whether the mileage compared is realistic can also not be judged and the consideration of the fuel supply for ICE cars is also not documented.

The findings conclude that electric cars emit 50 % less than diesel cars. This is the European average calculated for 2030. More detailed, the CO_2 emission reduction can amount to as much as 85 % in Sweden and only to 25 % in Poland, where there is still high contribution of coal powered plants to the electricity mix. In the outlook the authors state that with battery technology improvement and a rising share of renewables, emissions from battery production itself could be cut by 65 %.

4 Summary and conclusions from the survey

It becomes clear that this survey shows rather highlights and positions than a scientific analysis.

One major reason is the limited availability of data. Especially a detailed BoM (bill of material) analysis is difficult owing to the early market entry phase: data is kept strictly confidential by suppliers and manufacturers. A clear product trend is not discernible yet. All originally cited studies are based on many generic assumptions. And not all publicly available data, e.g. on battery composition and production processes, can cover the rapidly advancing development in industry. The resulting products will not be seen in the market before another few years from now.

In addition to that, the focus of the studies is quite different. Some highlight the battery production, some take a closer look at driving patterns and fuel or electricity supply in different regions, some compare vehicles of comparable size and utilization pattern and some analyse and compare small cars with very large and heavy cars, some attempt to include all steps in the value chain.

Table 2 compares the different coverage of aspects along the value chain in the five reports.

Check-List	Ingeniøren/ IVL	Carnegie Mellon	IFEU	MIT	VUB
Emissions from raw material production considered	✓	×	✓	✓	✓
Emissions from production and transportation calculated	(✓)	×	✓	✓	✓
Carbon footprint of battery included	✓	×	✓	✓	✓
Similar vehicle type/-class compared	×	✓	✓	×	?
Mileage realistic	✓	?	✓	✓	?
Supply of fuel considered	✓	✓	✓	✓	?
Local electricity mix applied	×	✓	✓	✓	✓
End of live considered – scrapping/recycling	(✓)	×	✓	(✓)	?

Table 2

The two theses introduced at the beginning of this survey were selected because they were discussed most controversial in the media.

1. 'EV batteries carry a heavy ecologic rucksack from production that cannot be amortized'
2. 'EVs are not green as long as we produce dirty coal power to charge them'

One could observe an increasing insecurity in the public about the ecologic benefit of electric vehicles to climate change due to inconsistent information.

This survey confirms how contradictory the reports are sometimes. And often the authors draw simplified conclusions about a very complex matter. However, despite the different focus and limited comparability of the publications one can summarize some basic findings.

4.1 Battery production must be as clean as possible

When coming to the market, EVs carry a heavier burden with an emissions rucksack of ca. +50 % over ICE cars. That is, when we compare vehicles of the same segment, similar size and similar weight.

One needs to bear in mind that today's EVs still provide considerably less range than an ICE car, e.g. some 200–300 km range for a compact car. Consequently, these cars will likely not be used in the same way and not regularly go on longer trips since also the necessary charging infrastructure is not overall installed yet.

Many studies use the prominent Tesla Model S or X with a 100 kWh battery for reference. This highlights even more the impact of a large battery on GHG emissions from production thus contributing to the CO_2 rucksack.

Although the efficiency of production processes and energy consumption in the value chain is still improving a lot and renewable energy will contribute its share in the future, this aspect should get appropriate attention.

4.2 Amortization of an ecologic rucksack is achieved during vehicle life

Whether the CO_2 rucksack can be amortized over the lifetime of a vehicle is dependent on the boundary conditions, mainly on the use profile (city or highway, load and passengers, total mileage) and the electricity mix in the country. Most studies conclude that in fact it is possible, also at today's standards. Even the 8 years amortization time calculated for a Tesla Model S by the Ingeniøren authors lies below the typical vehicle lifetime.

Amortization of the CO_2 rucksack may be achieved within 2–3 years for a compact car EV, as own calculations show.

4.3 Every km driven electric mitigates climate change

And locally, driving electric always has a benefit: no GHG emissions and less noise. When an EV replaces an ICE car, local pollution can be considerably reduced, and cleaner air is the result. Thus, even with electricity with a high emission share, e.g. from coal fired plants, EVs have a positive contribution to the local climate.

5 Changing the perspective – impact and conclusions from a higher ground

Changing the perspective and when looking at this survey from a higher ground and different angles some new insights can be gained.

With posing the questions in a different way and taking a more future-oriented solution-based approach some conclusions will be drawn on these two levels:

1. Mobility concepts of the future may need other metrics than a continued extrapolation from the past.
2. Optimizing vehicle utilization over lifetime solves more than one problem.

The reasoning follows from these conclusions:

5.1 Don't compare apples and pears

As already shown in the summary the metrics used do not match. See some aspects in Figure 3.

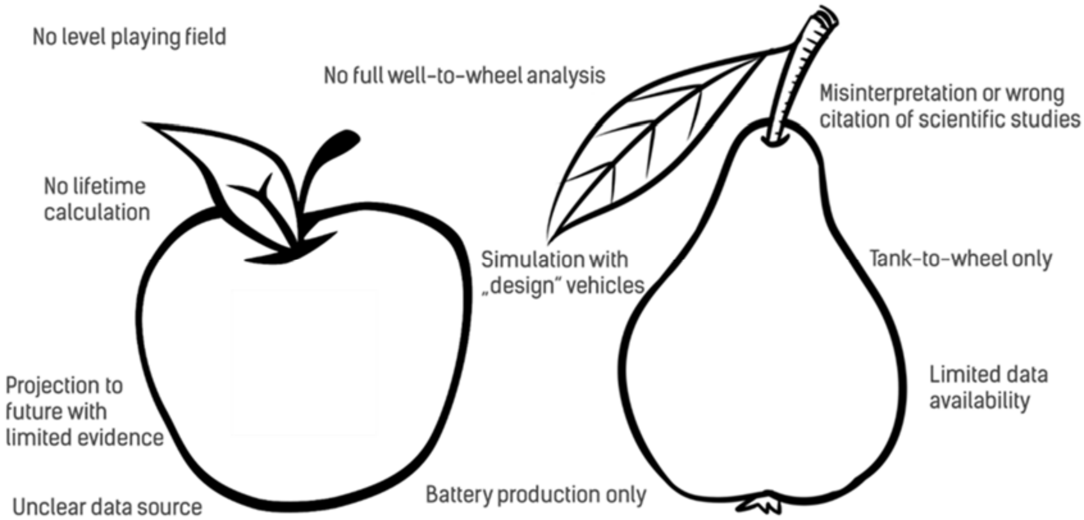

Figure 3

Different eco-balance elements are combined and the accounting principles for cars in production and utilization follow different metrics. The steps 1–3 from **Fehler! Verweisquelle konnte nicht gefunden werden.**2 cover the product itself in a well-to-tank analysis (see Figure 4). Then the step 4, the vehicle utilization, is described by a tank-to-wheel analysis. At the interface it is already not clear how to incorporate the fuel supply into the equation. Here, a shift is being made from kg vehicle to km driven.

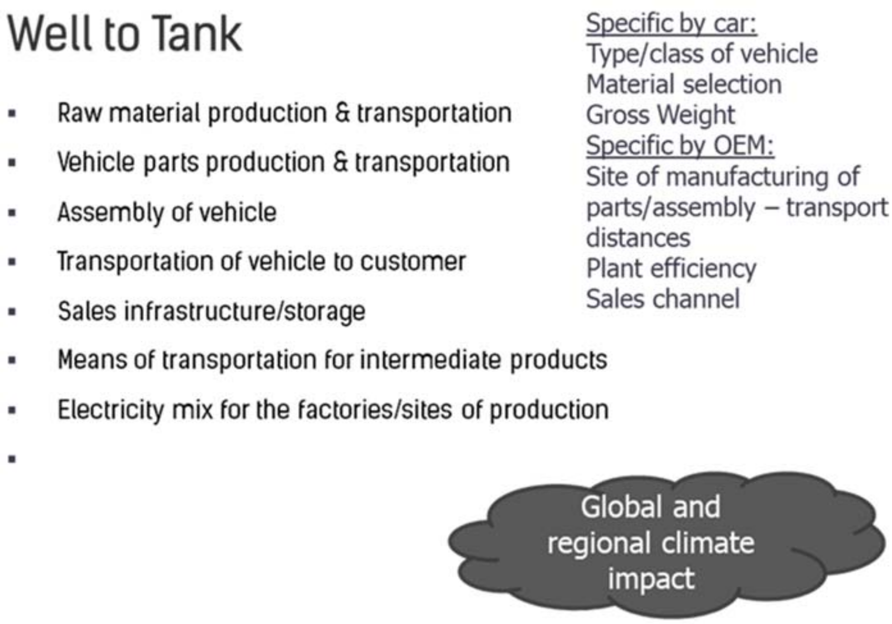

Figure 4

The responsibility is handed over: first, the OEM can influence the parameters by design of the car and the processes, then the user defines its utilization impact, but for simplification a standardized efficiency as defined by homologation is usually applied. The combination of both should give the well-to-wheel analysis.

What cannot be accounted for is the individual driving style (lead foot?), the payload and number of passengers transported, and in case of a PHEV the level of EV driving, that is the electric over fossil fuel share in the tank-to-wheel equation (Figure 5).

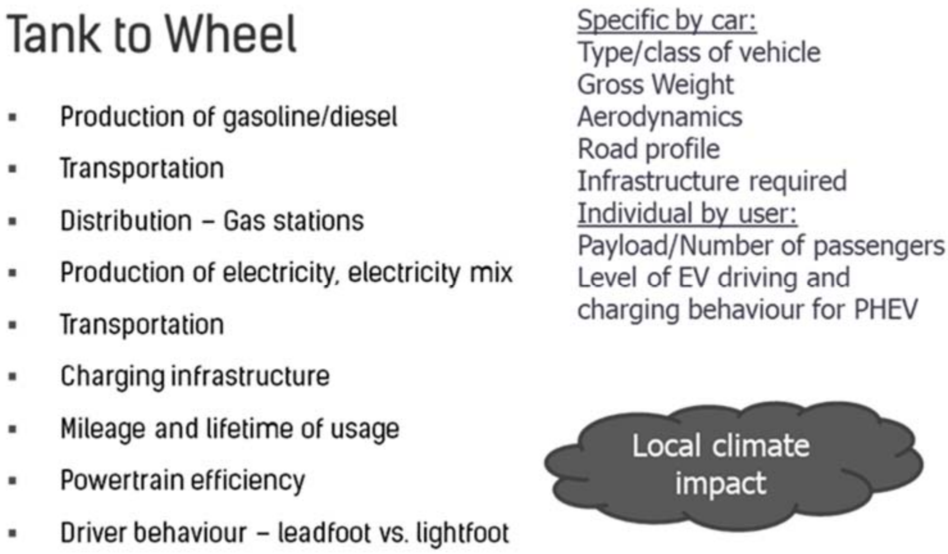

Figure 5

In view of the sharing economy concept and future autonomous vehicles as well as an already changing mobility behaviour enabled through digitization and app-based services, e.g. for more multi-modal individual mobility, the use cases will likely change. New vehicles such as people mover are introduced and ride sharing fits into a niche between public transportation and taxi services.

For a cradle-to-grave investigation scrapping and recycling needs to be included. Now, it gets even more complex when a 2^{nd}-life-use of the EV batteries needs to be considered. How to fit to the equation that batteries from several EVs are recombined in stationary storages that may serve a new purpose for several years before finally entering the recycling process?

On another level, emissions from steps 1–3 and likely 5 have a more regional up to global climate impact in view of the global economy and value chains covering transports over long distances. Step 4 has mainly a local climate impact. Therefore, the stakeholders involved may judge the results based on different criteria and priorities. In city centres where air quality is bad local zero emission mobility have an immediate and high valued effect also when it comes at the price of a still high emissions rucksack from production.

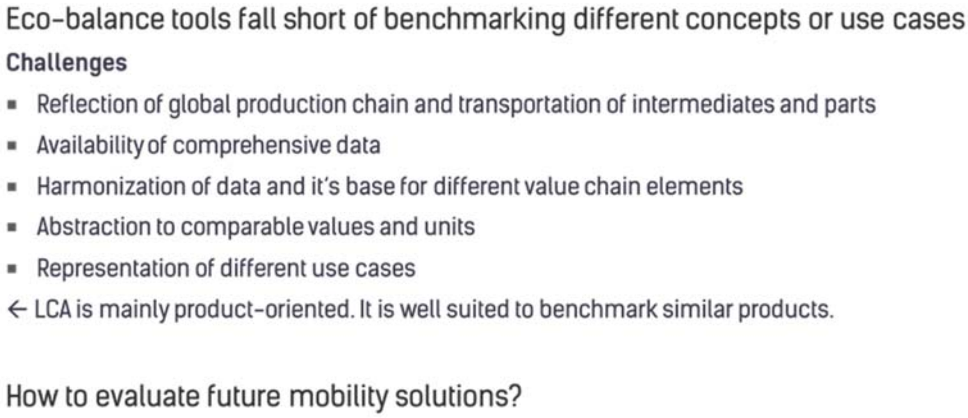

Figure 6

Figure 6 summarizes how traditional eco-balance tools fall short of benchmarking different mobility concepts or use cases.

5.2 Evaluate emissions per person km travelled

Mobility concepts of the future may need other metrics than a continued extrapolation from the past. With the introduction of new metrics and a shift to CO_2eq emissions per person km travelled for the evaluation of transportation means this could be served in a more holistic way.

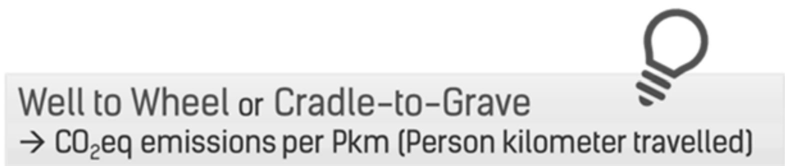

Figure 7

With this, the mobility footprint of the individual can be made transparent and allow for educated and responsible decision making of the consumer. It may also lead to transparent product evaluation and support design decisions in the industry. Even politics may support certain solutions or behaviour based on it.

5.3 Optimizing utilization solves more than one problem

Major levers complement each other: with 75–85 % of the emissions of a conventional ICE vehicle being produced in the use phase, for sure one should make best use of vehicles on the road. Sharing models, optimized traffic flow in cities and other measures enabled by digitalization will support this approach. Improved traffic guidance for parking, route planning and timing will also reduce traffic density and thus emissions.

5.3.1 Take passengers

One obvious solution is increasing the passengers per car and trip.

5.3.2 Share cars

Besides, increasing the utilization reduces the costs per asset. Especially in a business context this is useful, but also for private car owners. Lending the car to friends and family or renting it out during idle times raises the asset utilization rate.

Both is even more true for EVs: with initially still higher cost a high utilization pays back faster and with higher mileage at zero local emissions the climate benefit increases, and payback of the production burden is achieved faster.

The use phase today is accounting for ~60 % of the lifetime emissions of an EV, this share will be coming down to ~40 % by 2030.

5.3.3 Turn lead-foot into light-foot

Driving style can contribute. One example: reducing consumption from 6.8 L/100 km to 5.8 L/100 km yields in 15 % emission reduction and thus 155g/km. That results in emission savings of 0.3 tons per year and 5.4 tons over 18 years. Moreover, it saves 15 % fuel ~ 120 L and thus the respective expenses.

All these measures contribute to ecology but also to society:

- the reduction of local urban emissions,
- the improvement of a tight parking situation → comfort and cost
- the reduction of time spent in stop-and-go traffic and with searching for parking → comfort, costs and time

5.4 Make best use of vehicles on the road

Another way of making best use of the vehicles on the road today is extending their lifetime.[4] The analysis, calculated for Germany, shows, that keeping older cars with lower emission standards on the road and switching to EVs later is beneficial compared to scrapping them now for a slightly improved ICE car, at least when calculating the CO_2eq lifetime emissions. In the "variable emissions" equation (Tank-to-

[4] In Germany the average life of passenger cars today is 9.3 years. But the typical lifetime is 18 years, some models reach 22 years life and more before scrapping.

wheel) EV will come down to ~50g/km CO_2: 0.6 tons per year versus 1.86 tons with ICE cars today.

As Figure 8 shows, the earlier exchange of a Euro 4 car for a Euro 6 car leads to higher emissions than changing to an EV four years later or even continue driving the Euro 4 car for another 10 years. Adding a higher production rucksack with an EV is compensated after 4–5 years, when instead also adding the ICE rucksack of the new Euro 6 car.[5]

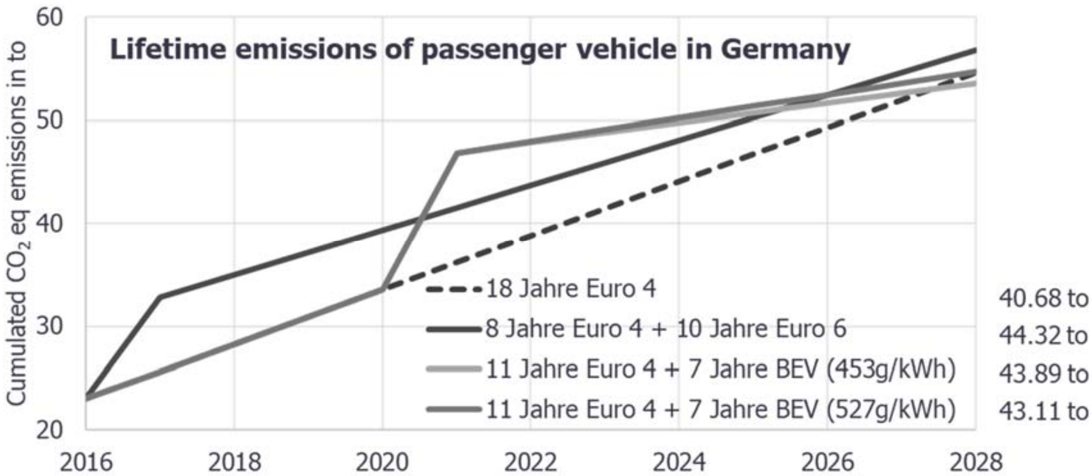

Figure 8

Over a 10-year period one can save nearly 4 tons CO_2eq per vehicle. When looking at the car population in Germany (Figure 9[6]) this adds up to a savings potential of some 60 million tons of CO_2eq, that is 6 million tons per year.

[5] Reference: KBA; own calculations. Annual mileage 12.000 km; 1st purchase Euro 4 in 2010, time use starts 2011; new Euro 6 in 2017→2018, new BEV 2022→2023 resp.; well-to-tank: 7.2 to/ICE, 10.7 to/BEV; Tank-to-wheel: 155g/km CO_2 Euro 4, 128 g/km CO_2 Euro 6; BEV German electricity mix of 2016/prognosis average 2022–28.

[6] Data: KBA; total population ~45 million passenger cars

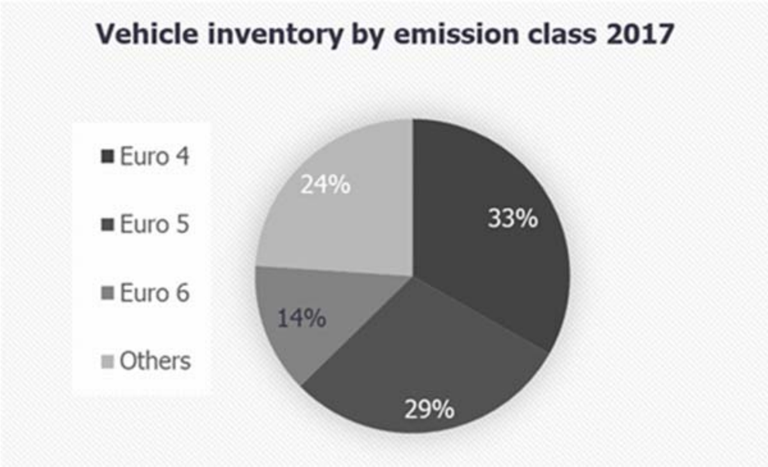

Figure 9

6 Summary and Outlook

A major learning from this survey is: one should change the perspective when looking for guidance. Pursuing the methods of the past must not help for evaluating the future. And then, also future mobility behaviour may be different from the past.

Not only the product analysis is still difficult, also the customer behaviour does not follow standard patterns – which use cases will be matched with which type of EV, will the passenger rate per car raise and more sharing take over in the future or will the individual one-on-one relation to privately owned cars prevail?

6.1 The Energiewende will benefit EV solutions globally

The IVL study reveals that 80 % of the battery emissions rucksack result from production and 20 % from mining and transportation of the raw materials. This means that there is a huge lever when GHG emissions in production are reduced with increasing the share of renewables used for it.

The European average of renewable energy production today is ~20 %, in Germany it is ~30 %, in the US ca. 15 %. The German government targets are: 50 % by 2030 and 80 % by 2050.

All along the value chain of the battery, there are improvements being made:

- With the selection of raw materials and the composition of electrodes environmental standards are considered.
- The energy density is being improved from generation to generation; that means a better yield per resource input. It also contributes to the vehicle design in a positive way, allowing smaller batteries to provide longer driving range.

- The longevity of batteries through thermal and electrical battery management is improved a lot which prolongs the lifetime in the application.
- Reuse (e.g. 2nd life applications) and recycling strategies and processes are developed and will be implemented. This prevents from early scrapping and ensures maximum use of the raw materials and resources included.

The calculation shows that with a reduction of ~33 % of emissions in production, transportation and recycling/scrapping EVs would match ICE cars in the "fixed emissions" equation (Well-to-tank). Based on current prognoses, this is within reach very soon.

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